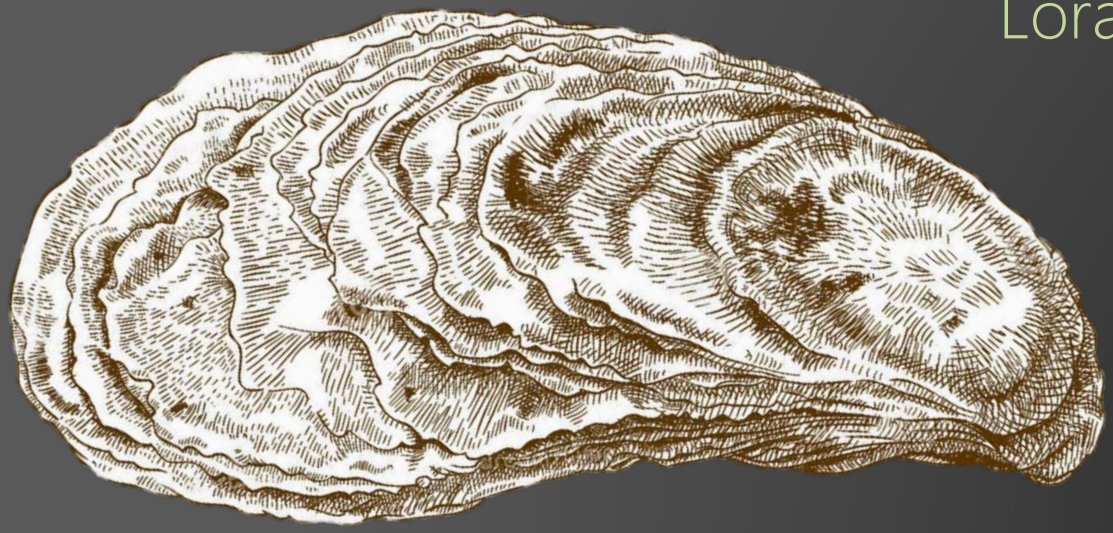
ReeFBioDES: The Oyster Reef Filtration, Biodeposition, and Ecosystem Services Model



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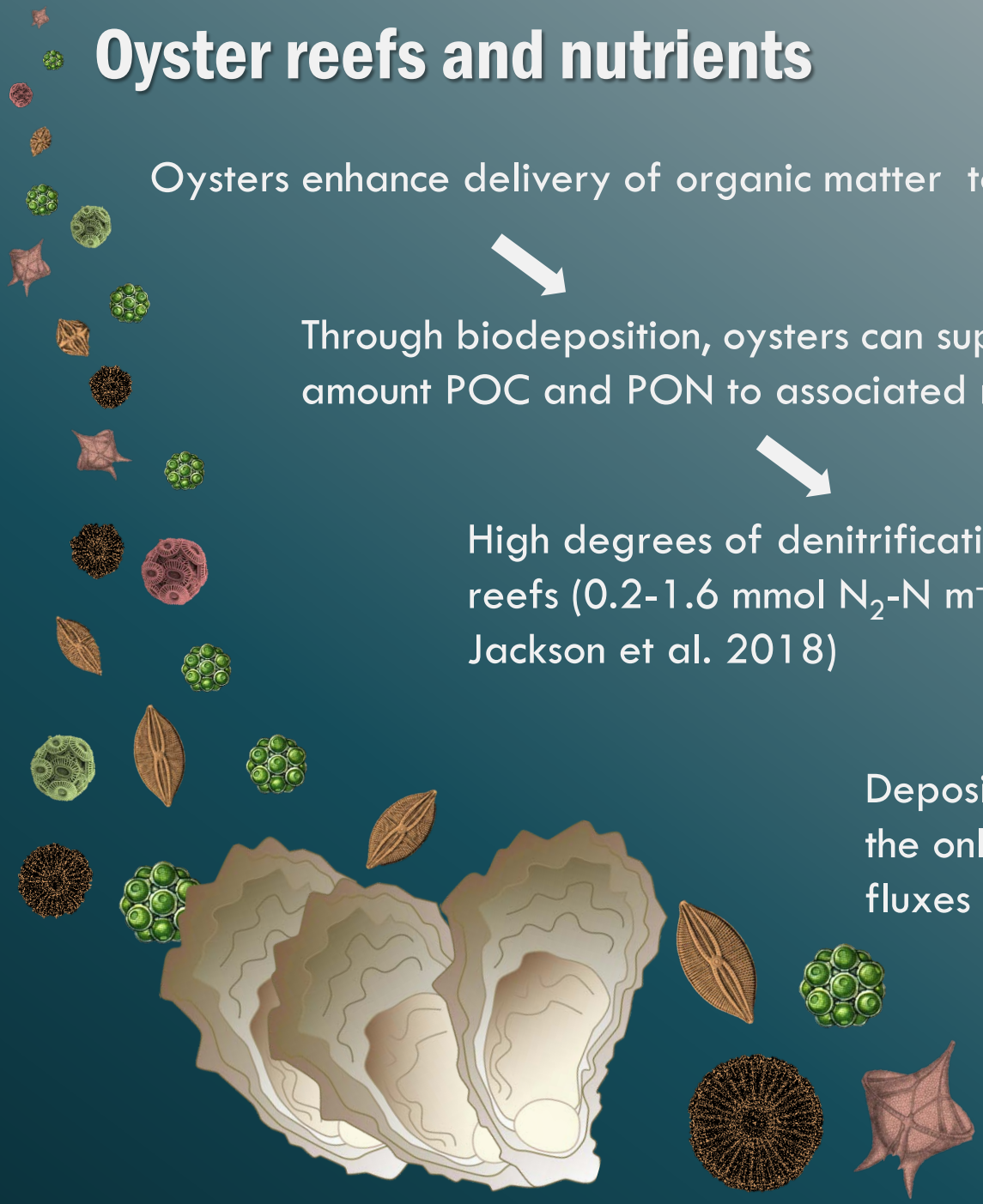
Oyster reefs and nutrients

Oysters enhance delivery of organic matter to the benthos

Through biodeposition, oysters can supply a substantial amount POC and PON to associated reef sediments

High degrees of denitrification have been found on restored reefs (0.2-1.6 mmol N_2-N m^{-2} h^{-1}) (Kellog et al 2013; Jackson et al. 2018)

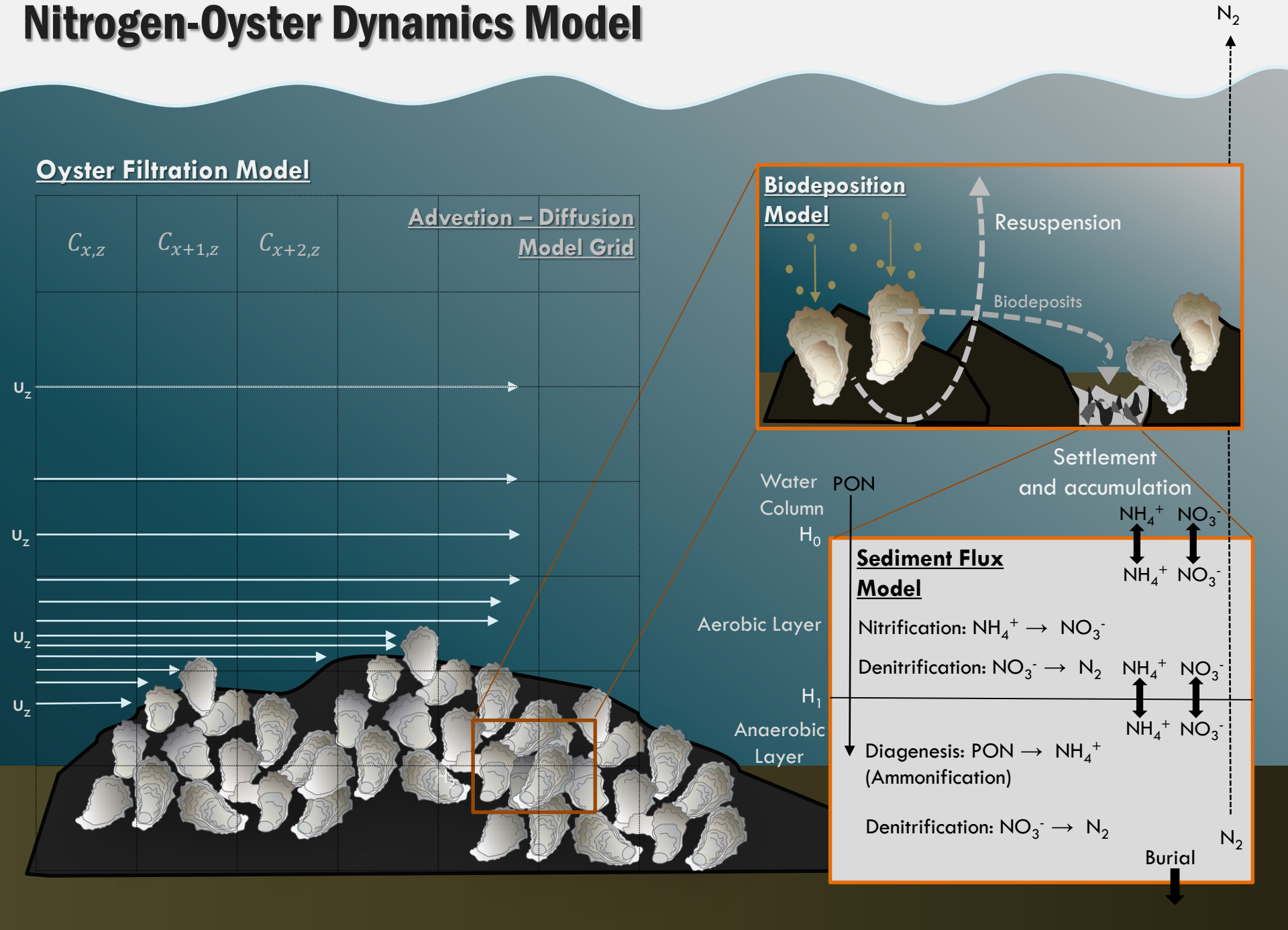
Deposition of biodeposits likely not the only process responsible for the fluxes that have been observed



Model Overview

How does it work?

Nitrogen-Oyster Dynamics Model

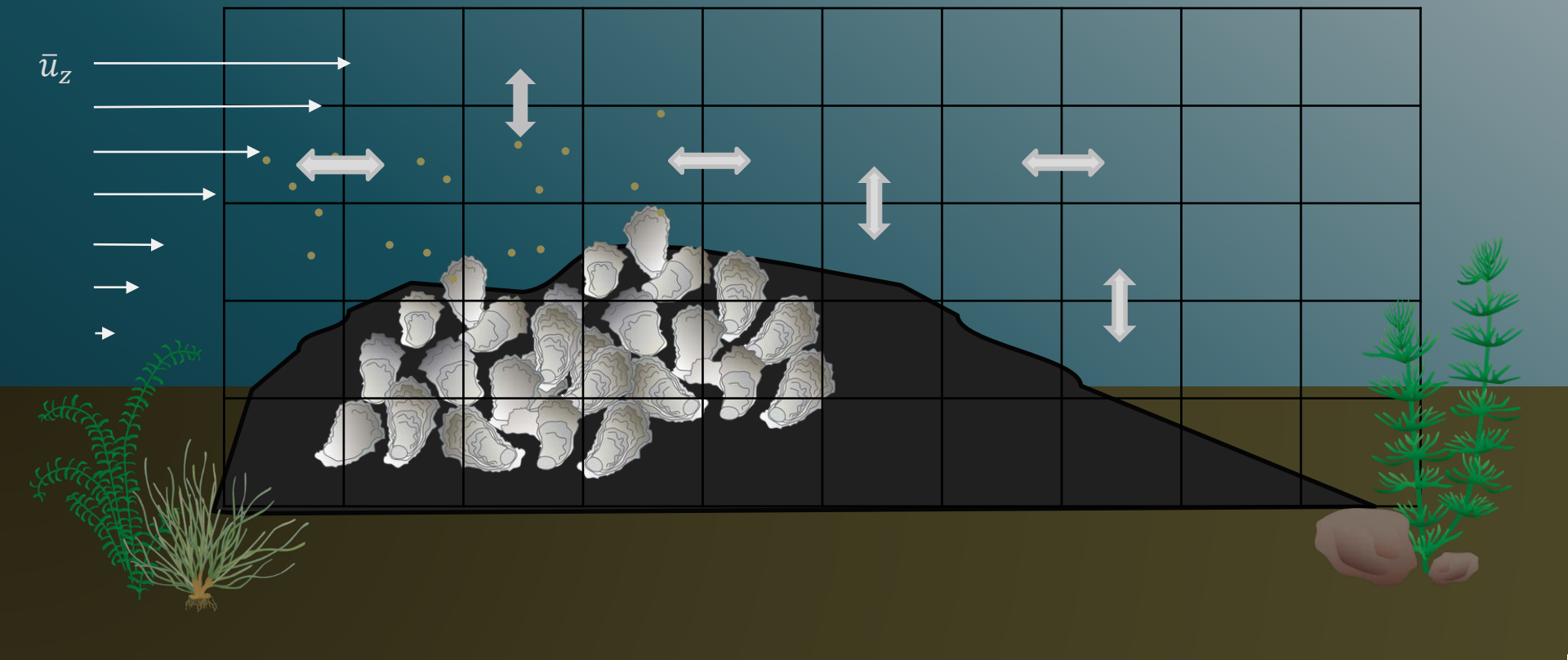


Chlorophyll over the Reef Advection-Diffusion Model

$$\frac{\partial C}{\partial t} + \frac{\partial uC}{\partial x} + \frac{\partial wC}{\partial z} = \frac{\partial}{\partial z}\left(K_z \frac{\partial C}{\partial z}\right) + S$$

- Δ in concentration over time
- advection
- sinking
- vertical turbulent diffusivity
- Removal

Use 2D grid to track changes in Chl-a over the reef



Filtration Model

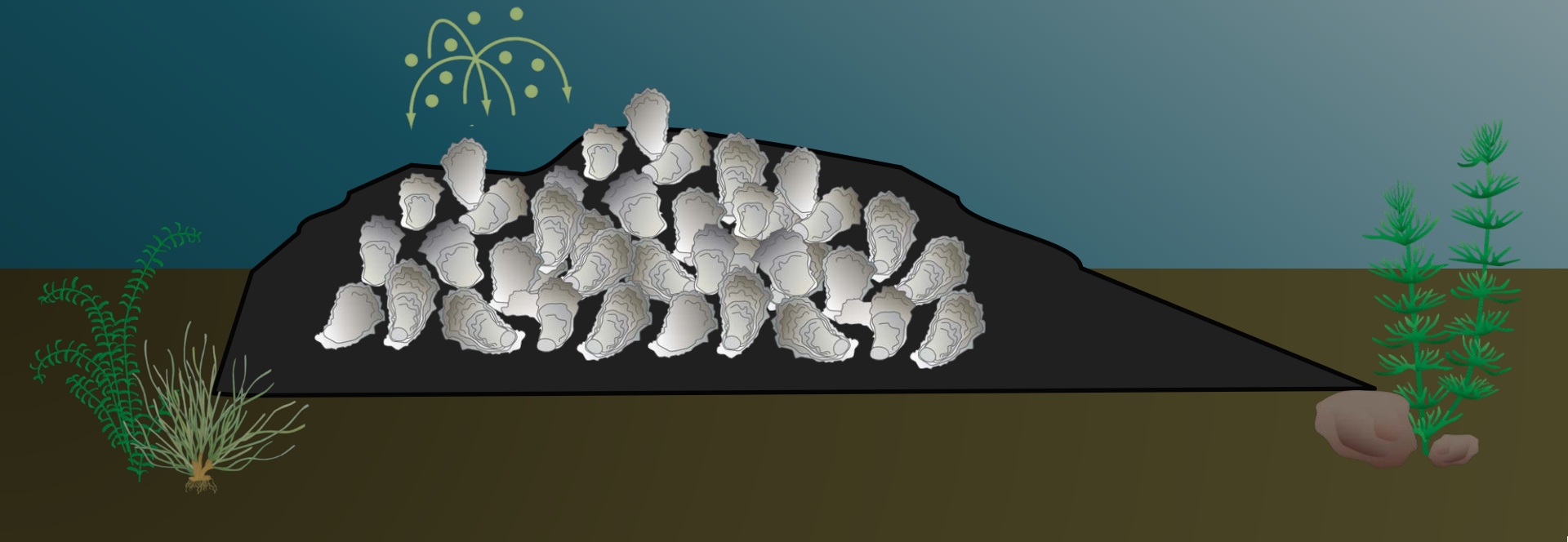
Filtration Rate (m^3 $oyster^{-1}$ day^{-1}):

$$FR_{(i)} = 0.17 \times W^{0.75} \times f(T) \times f(S) \times f(TSS)$$

(Ehrich and Harris 2015)

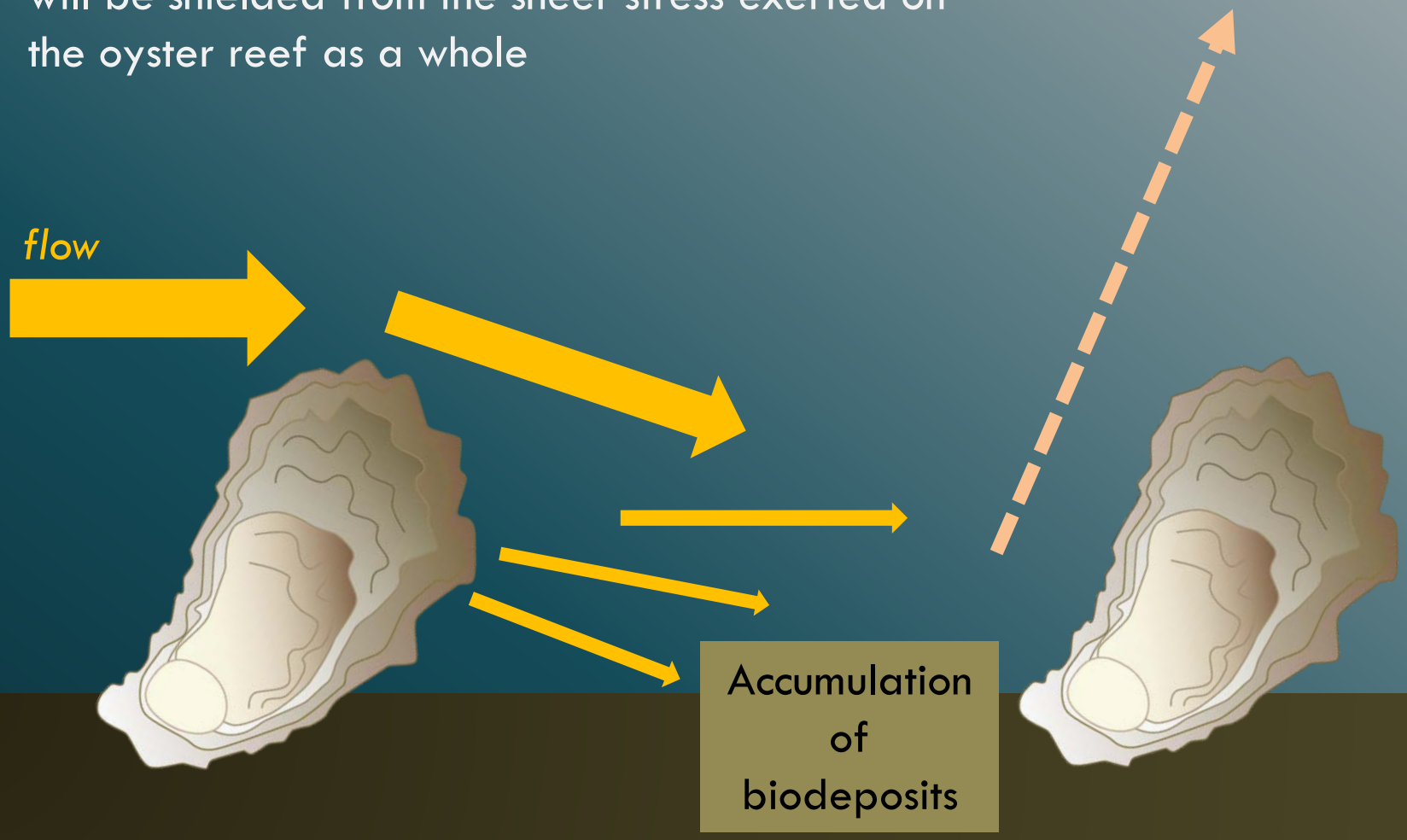
Filtration rate is a function of:

- temperature
- salinity
-concentration of total suspended solids



Biodeposit Transport

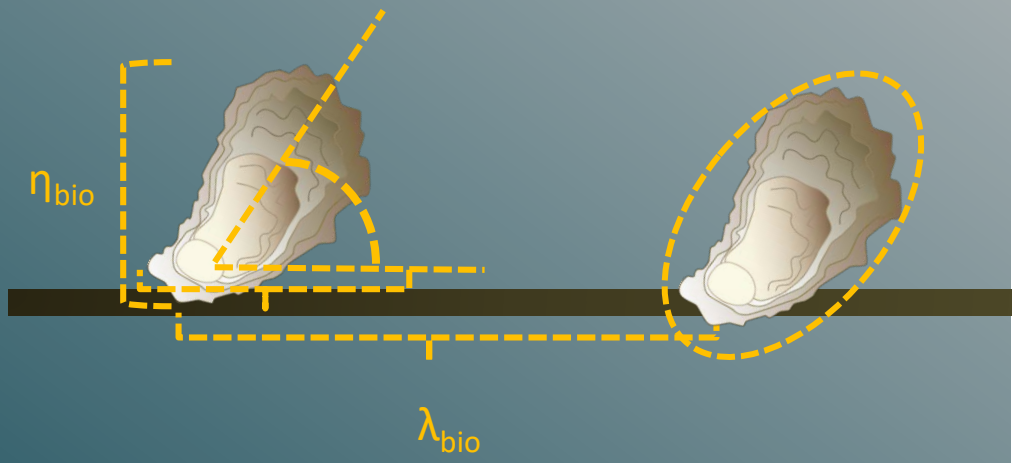
The biodeposits accumulating between oysters will be shielded from the sheer stress exerted on the oyster reef as a whole



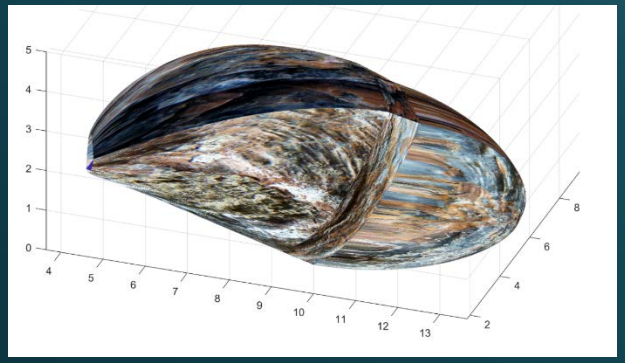
Biodeposit Transport

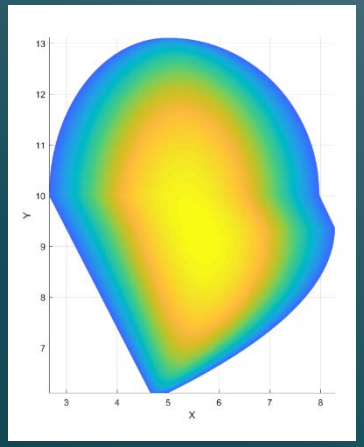
The amount of shear stress exerted on the biodeposits depends on:

- The small-scale geometry of the oyster bed
- Hydrodynamic conditions
- Size of biodeposits



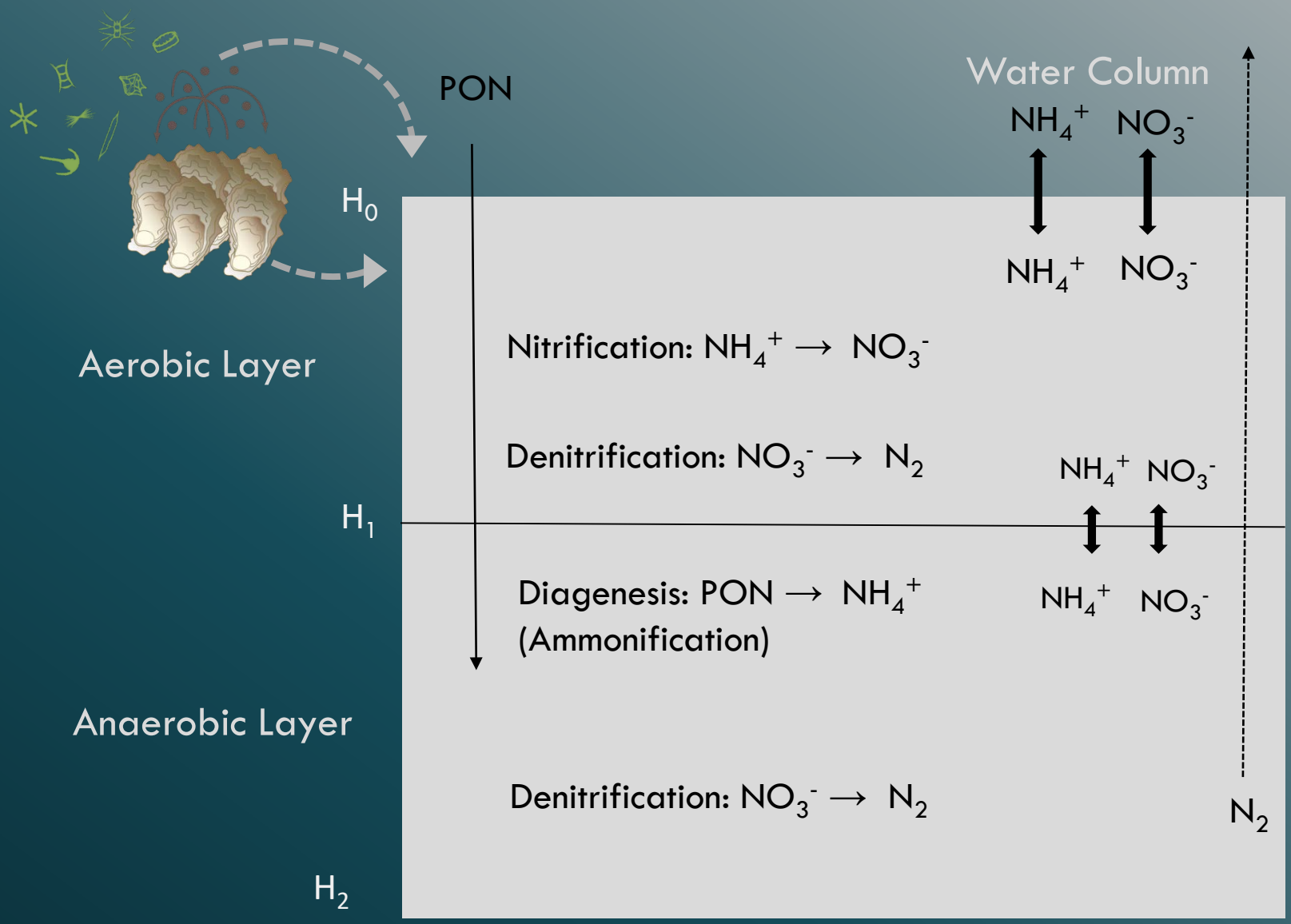
Therefore, we had to find innovative solutions to simulate the factors that influence resuspension:





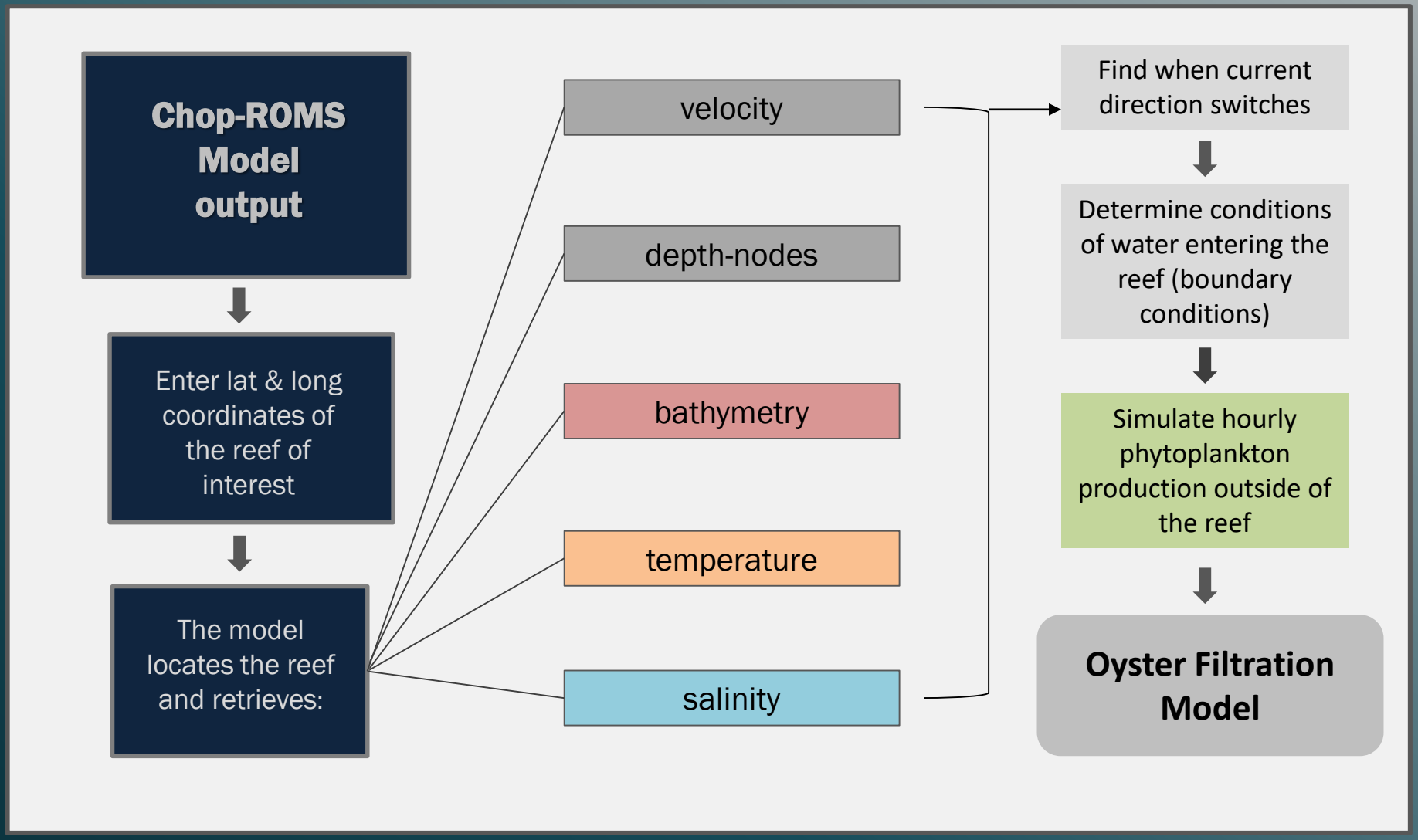
3D oysters allow us to retrieve important features of roughness geometry

The final piece… the sediment flux model

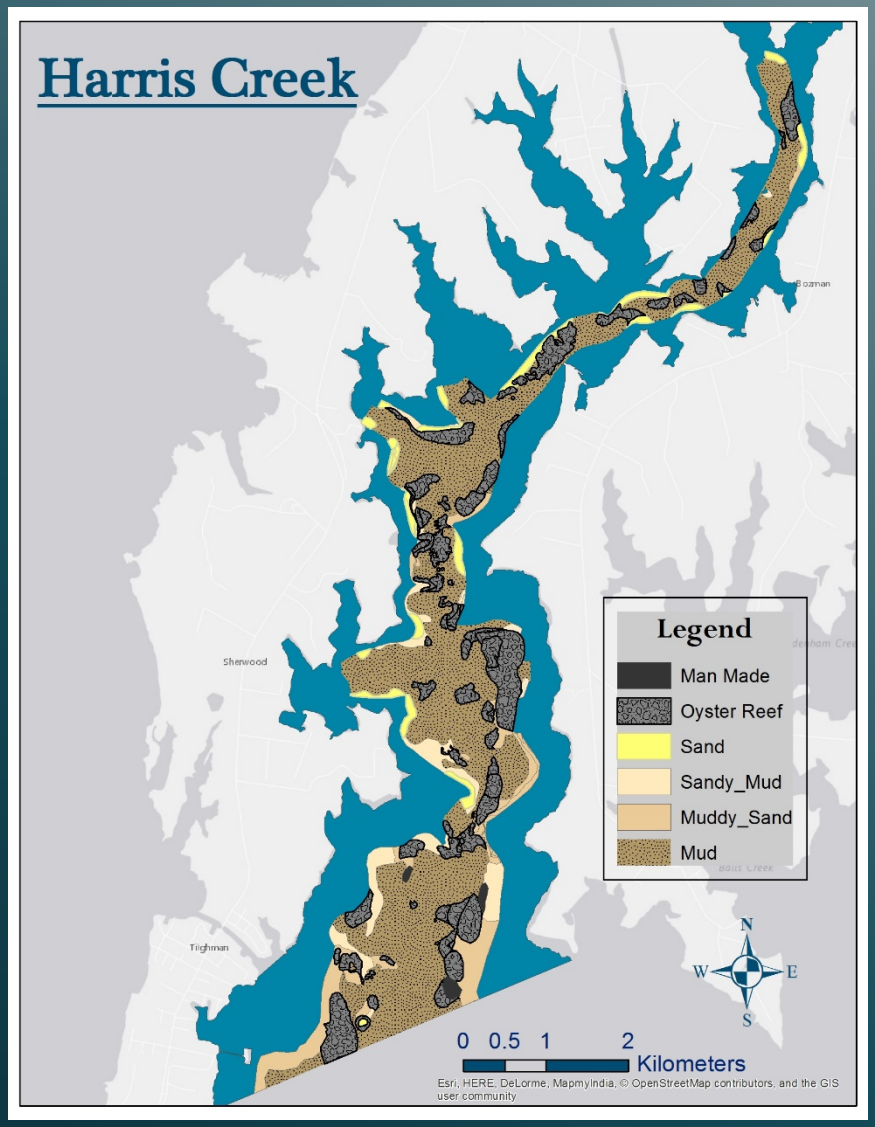


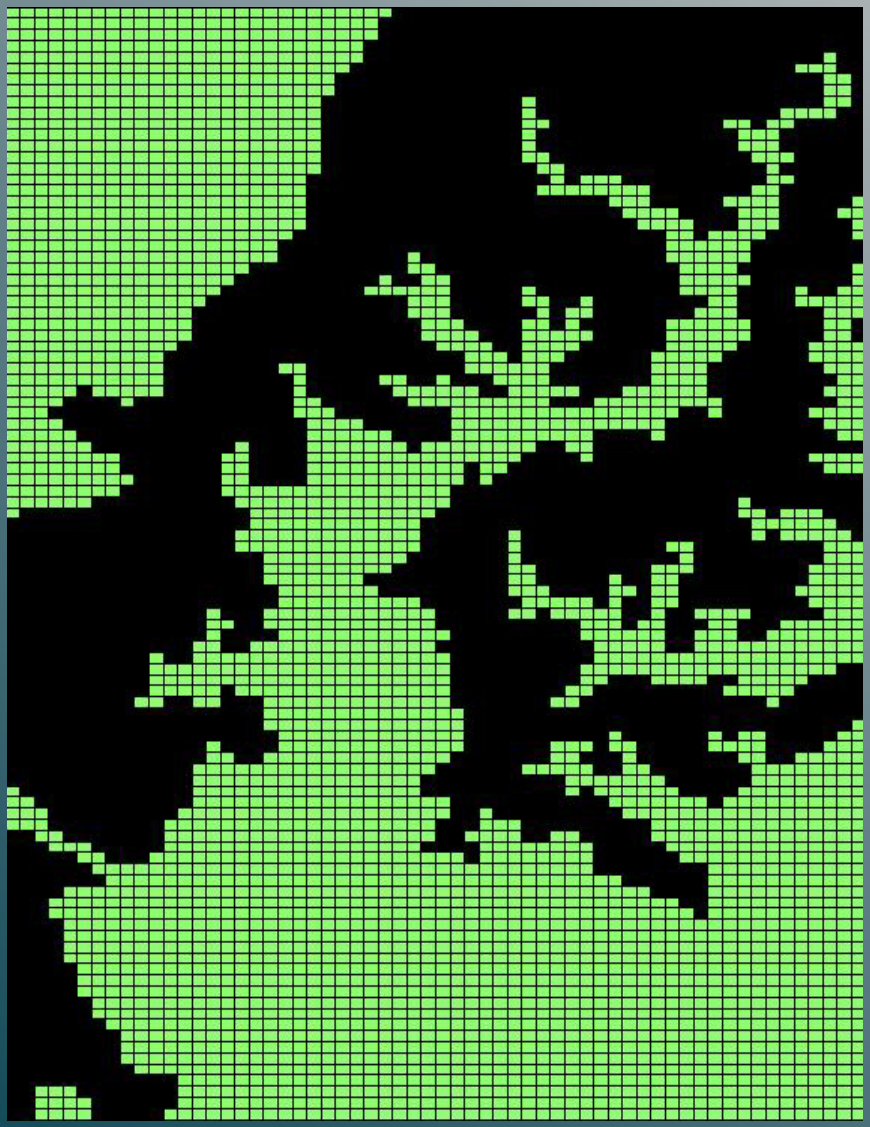
Forcing Functions

How do we get values for the environmental variables?



Filtration Model – where to parameterize?

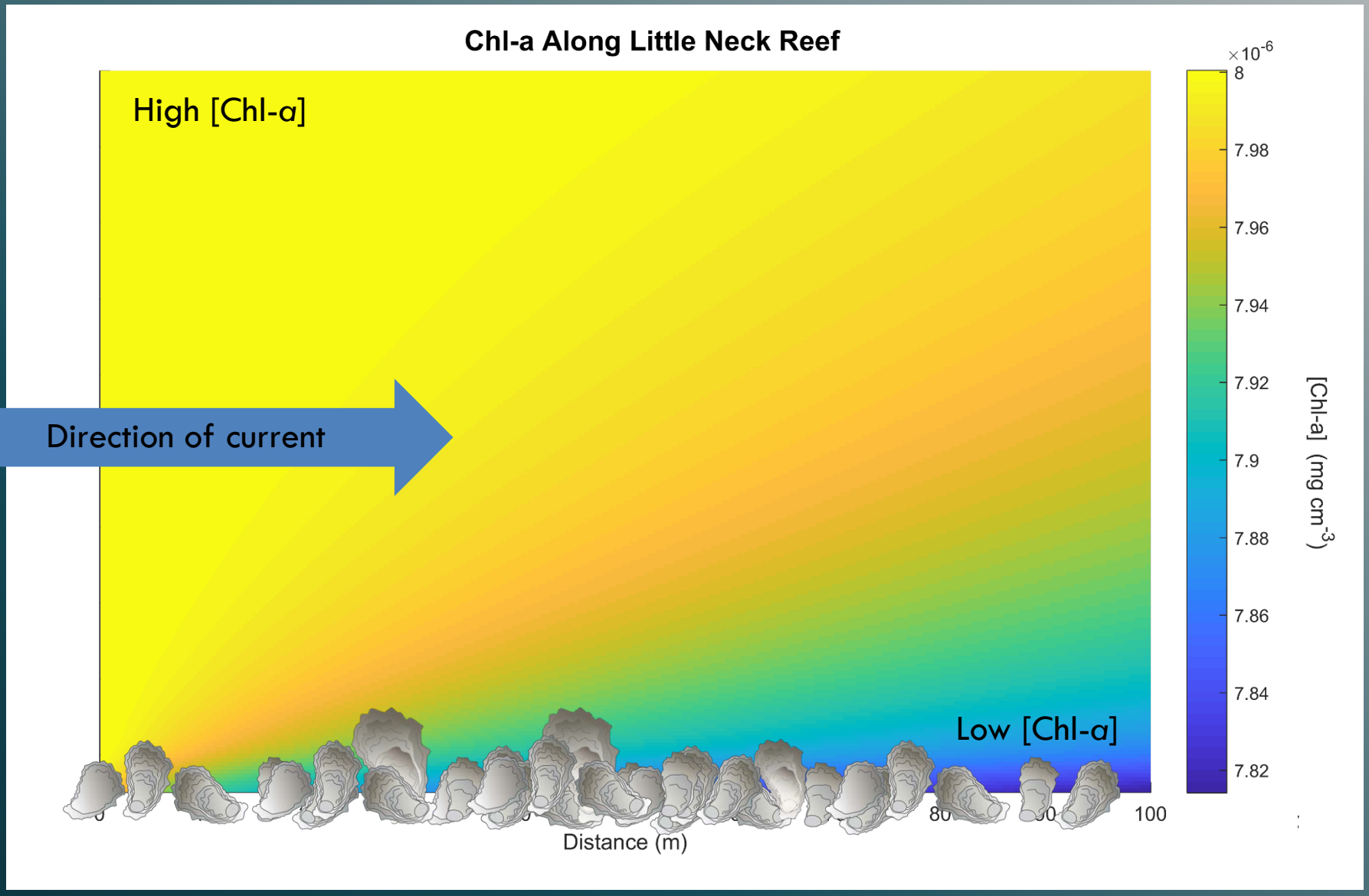




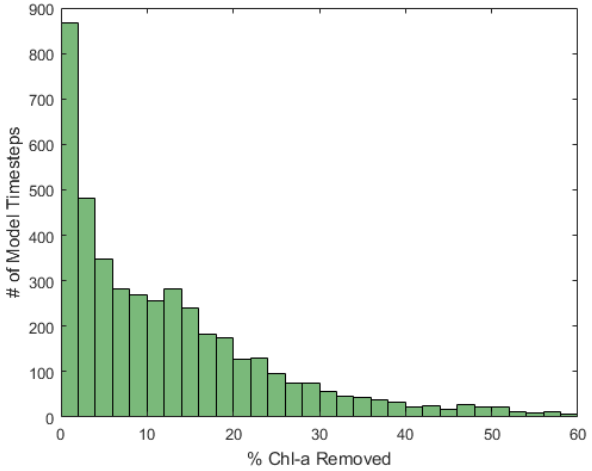
Preliminary Results

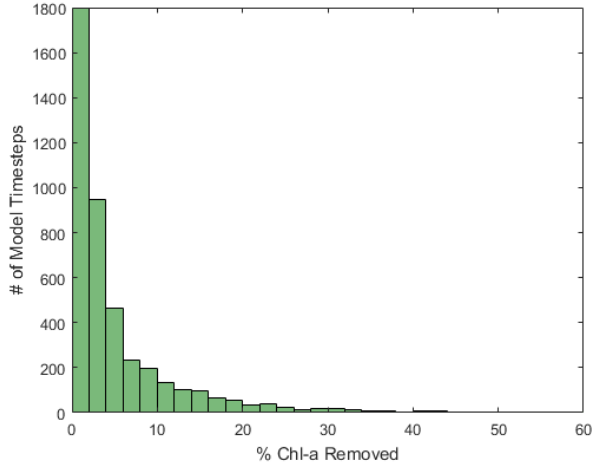
What did we find?

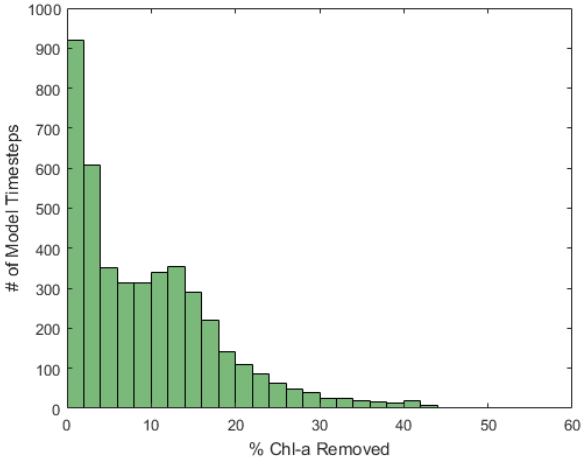
Filtration Model

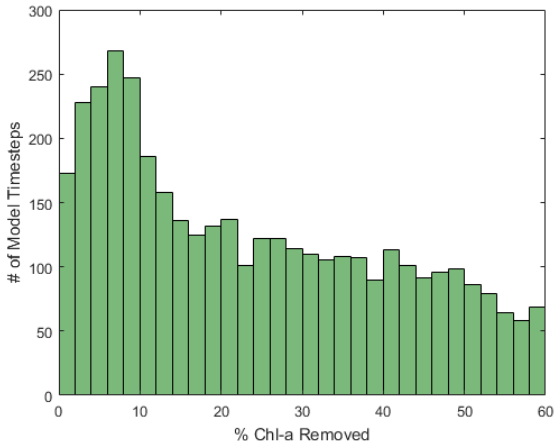


Different reefs have different Chl-a removal efficiencies



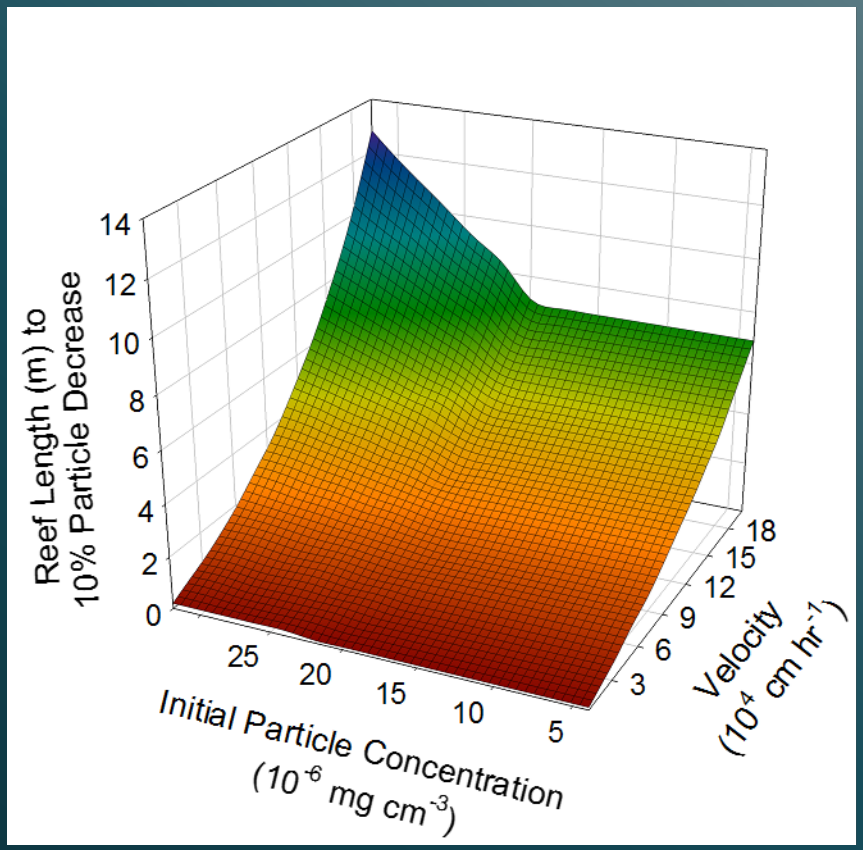




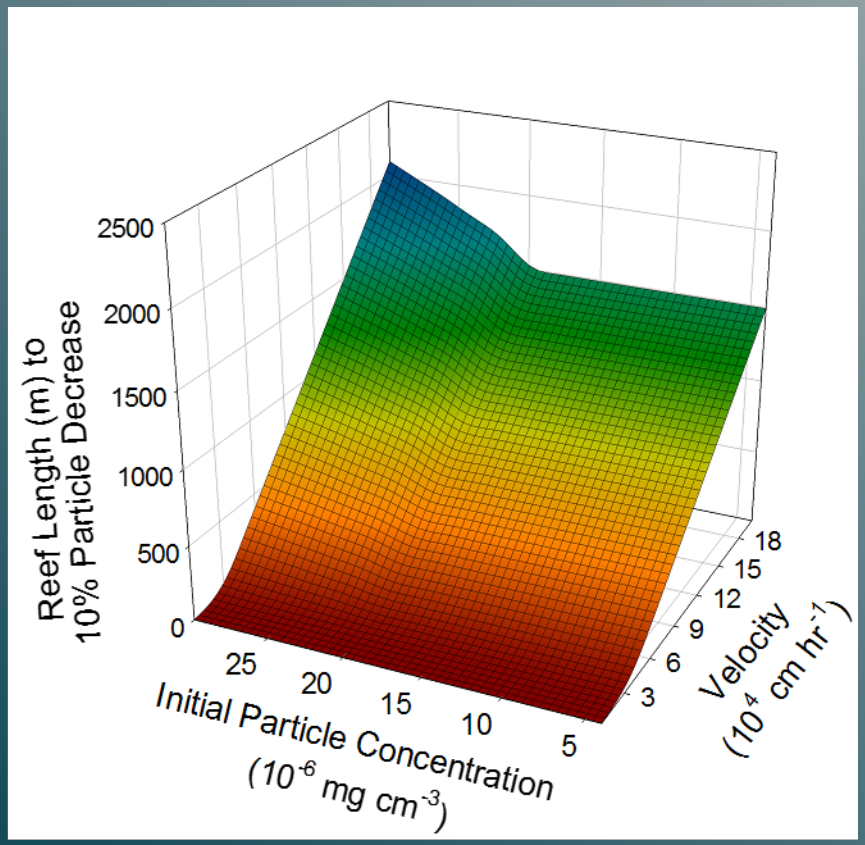


Implications for restoration design

700 oysters m^{-2}



50 oysters m^{-2}

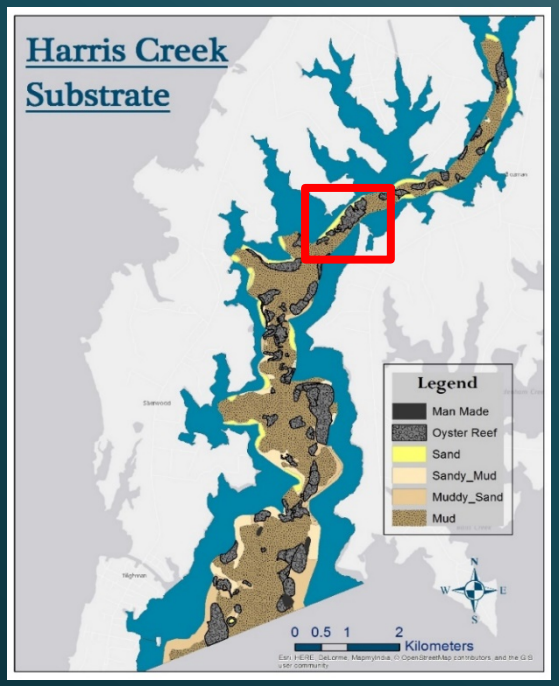


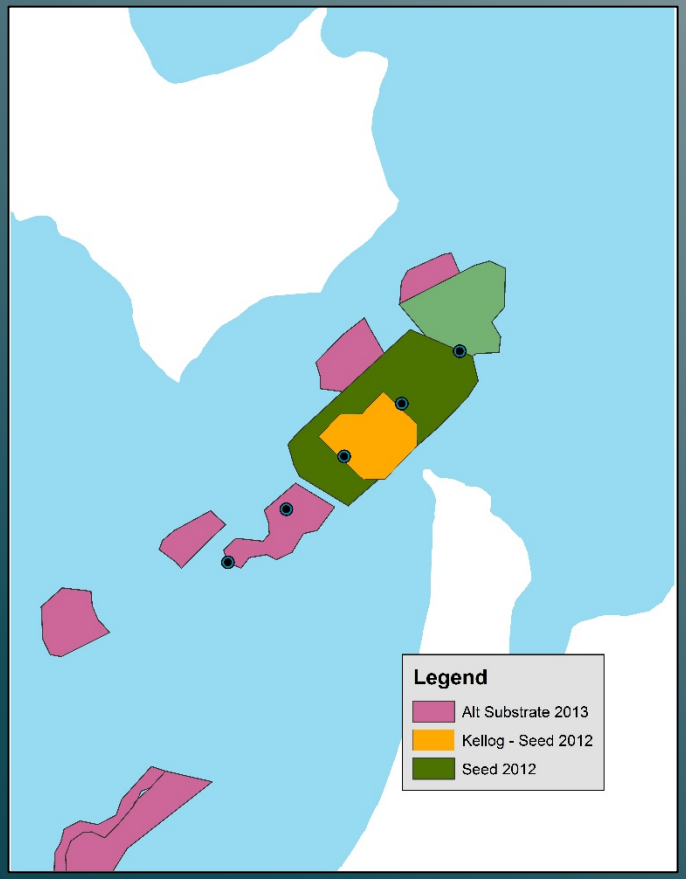
Model Validation – Little Neck Reef

Instruments:

- Acoustic Doppler Profiler
- Laser In-Situ Scattering Transmissometer
- CTD profiler – Optical Backscatter Sensor

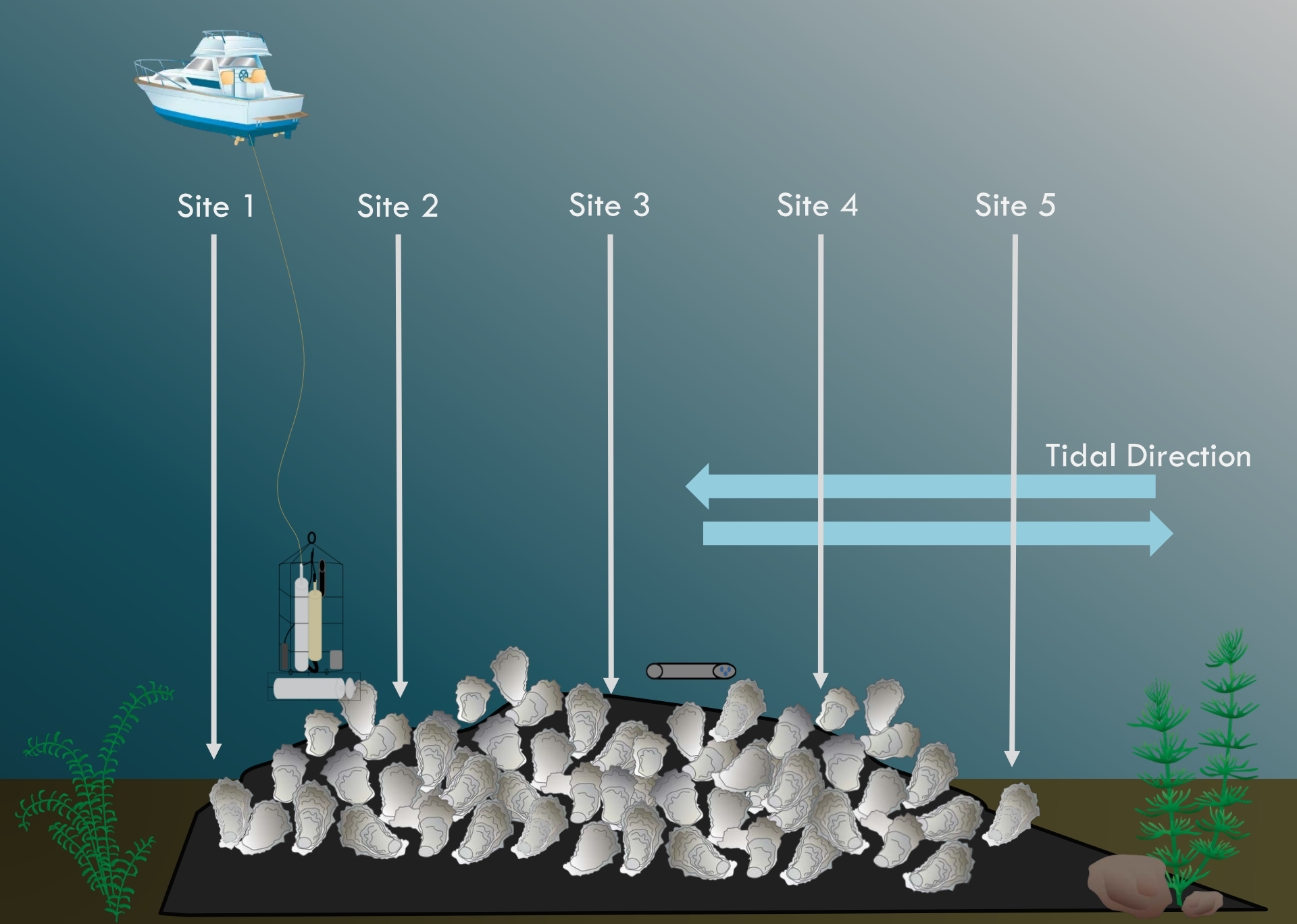
Little Neck Reef:





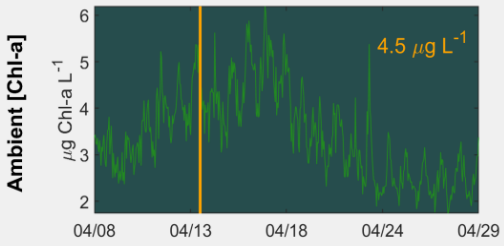
Discrete sampling stations on Little Neck Reef,

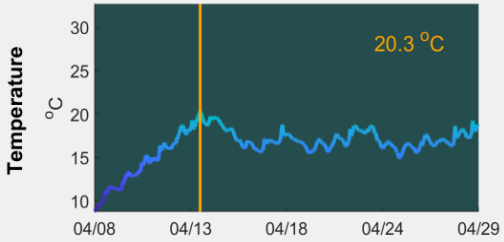
Different areas fo the reef have been subject to different restoration methods



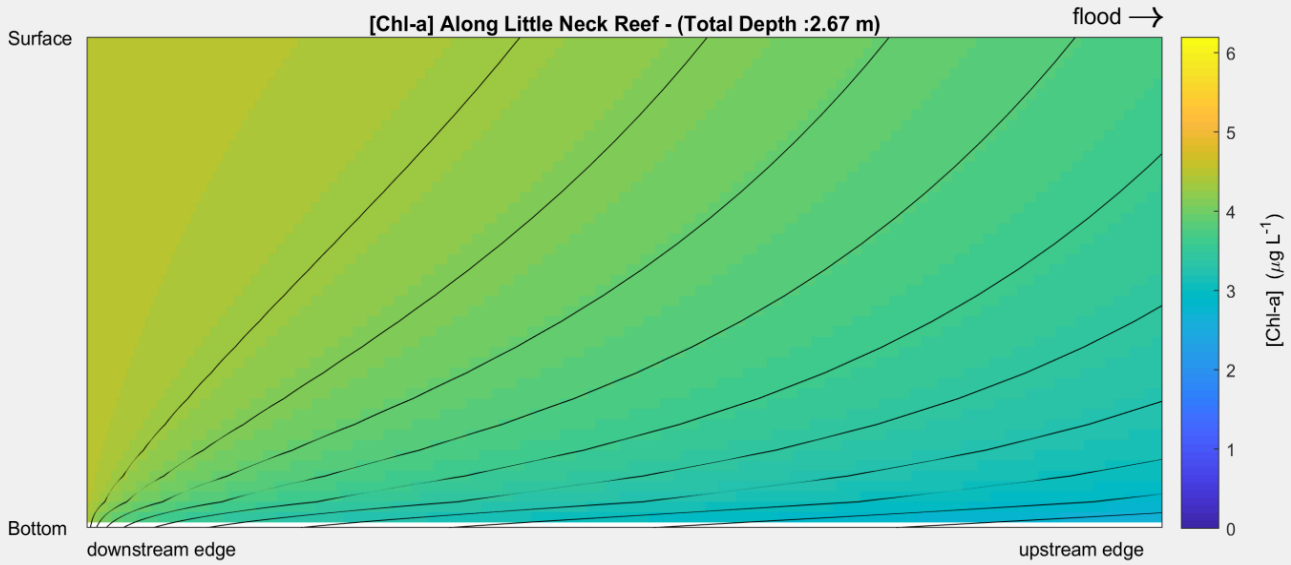
Schematic that depicts the planned sampling regime over the Harris Creek oyster reef (graphic by Givens and Kahover)

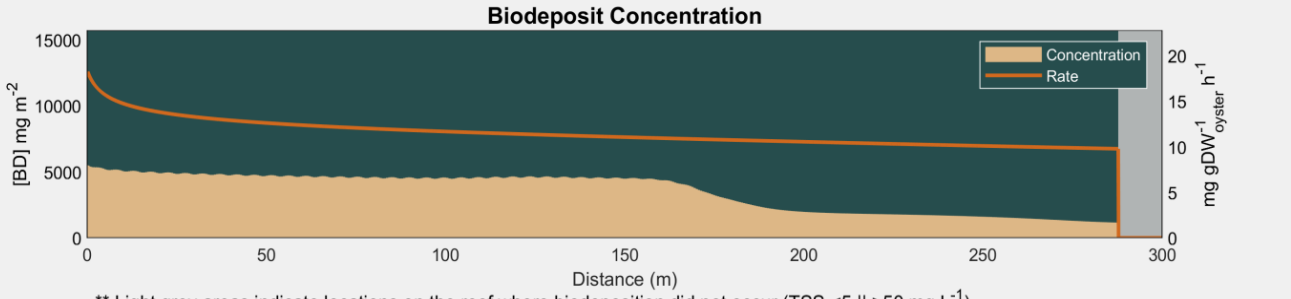
Model Simulation





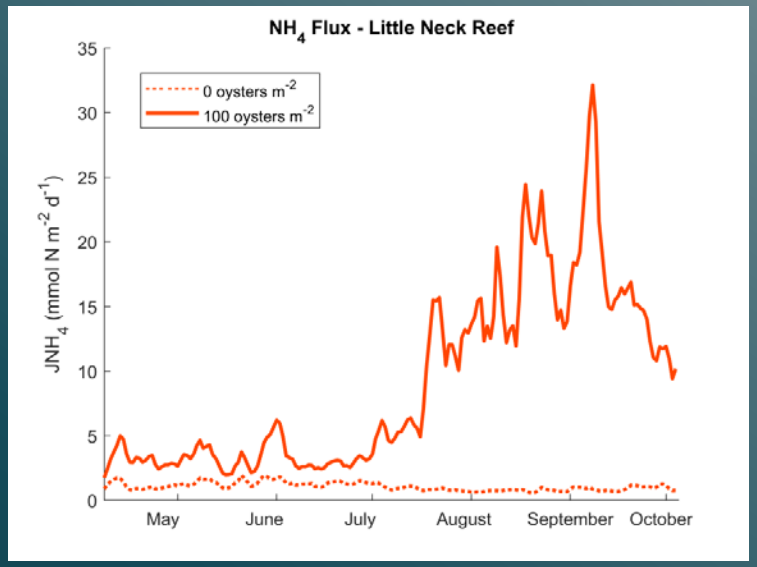
April 15, 2010 1:00 AM

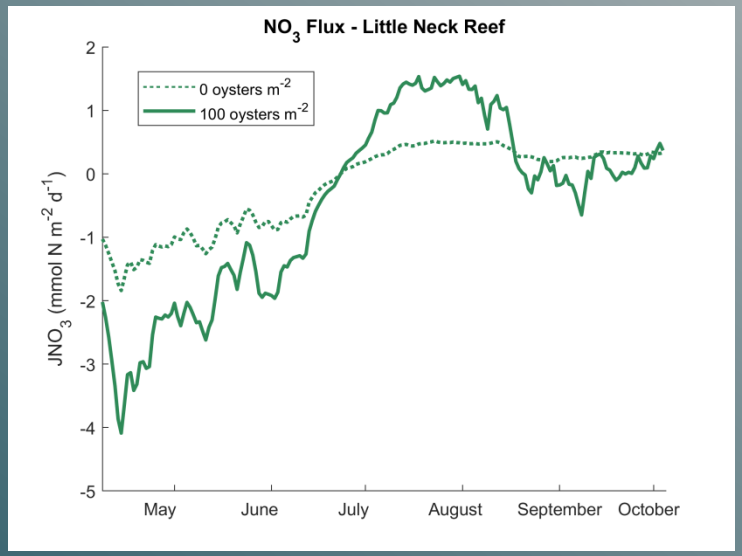


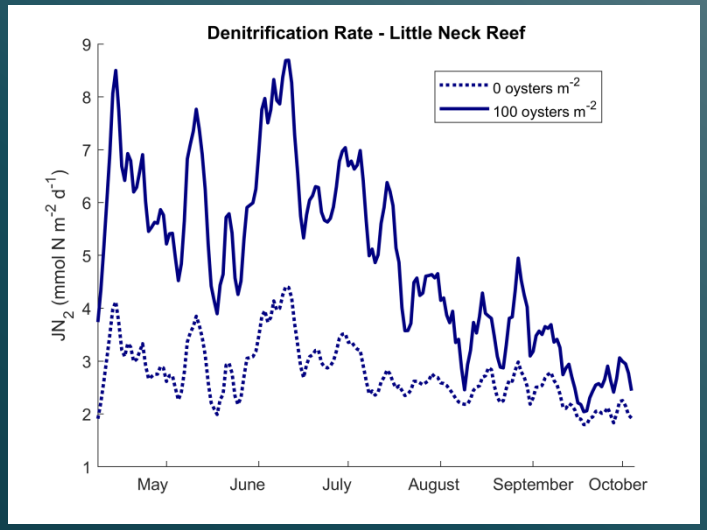


** Light grey areas indicate locations on the reef where biodeposition did not occur (TSS <5 || >50 mg L^{-1})

Model Simulation







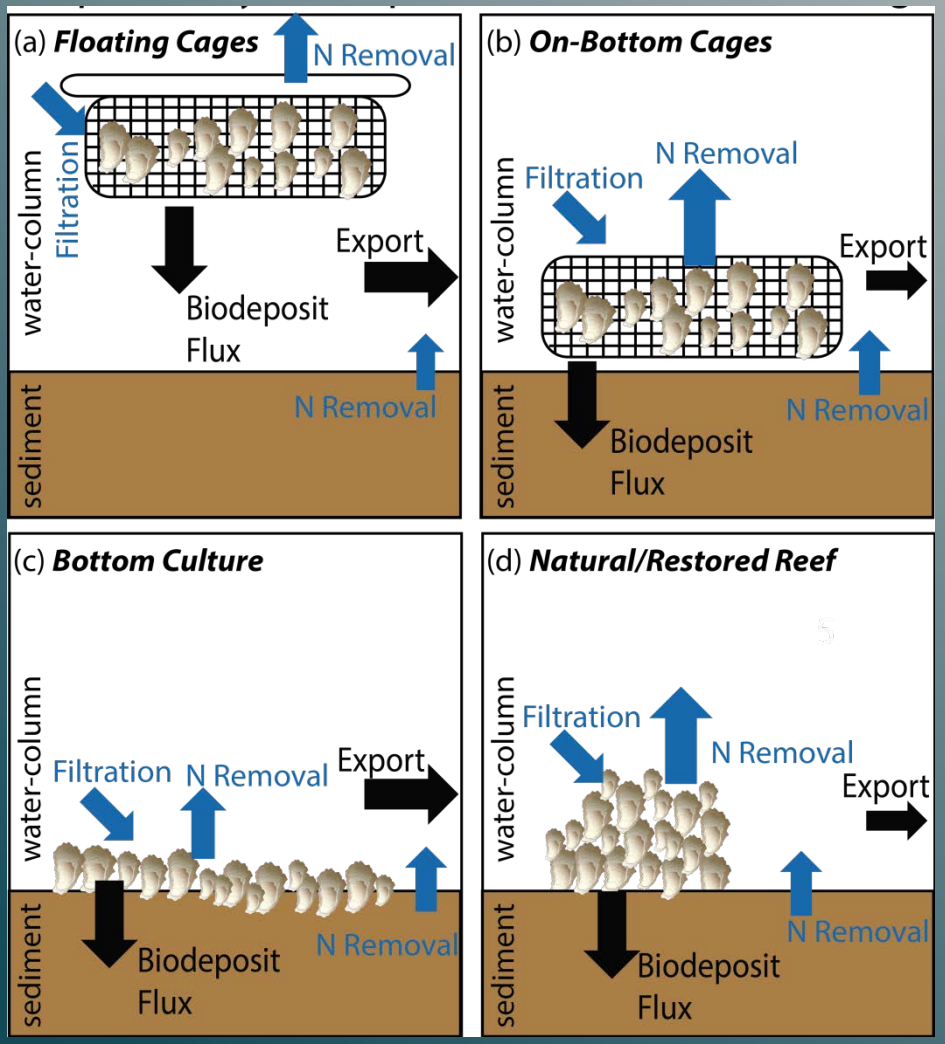
Take Home Messages

- Oysters interact with tidal waters, impacting both local hydrodynamics and particle concentrations in proportion to size and density
- The sediment flux model predicts a large impact on ammonium fluxes as a result of oysters, changing these from nearly zero to in excess of 25 mmol N m^{-2} d^{-1}
- Nitrate fluxes are not significantly changed by the presence of oysters
- Denitrification rates increase three times background levels, and are comparable to observations by Jackson et al. (2018) 4.8 - 14.4 mmol N m^{-2} d^{-1}
- Increased ammonium fluxes were not matched by denitrification rates, suggesting a net release of nitrogen from biodeposits to the water column

Ongoing Work: Apply ReefBioDES in A Variety of Oyster Aggregations

Sea Grant Maryland

"Quantifying nitrogen removal potential in oyster reefs versus aquaculture in response to hydrodynamic setting and water quality"



Acknowledgments

https://ceem.cbl.umces.edu/

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Funding for this project was provided by NOAA's Chesapeake Bay Office

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